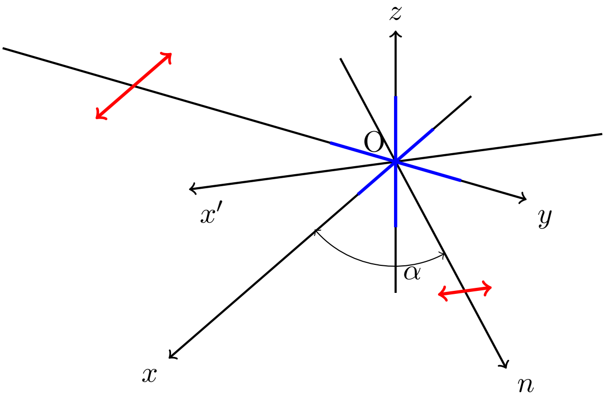
Geometric representation

Radiation of a non relativistic charge accelelerated free or bound (electron in the classical description with oscillators)

$$\vec{E_{rad}} \propto \vec{n} \times (\vec{n} \times \vec{a}) \tag{1}$$

Geometric representation

Electron accelerated by a force due to the electric field of polarized radiation (Thomson scattering)



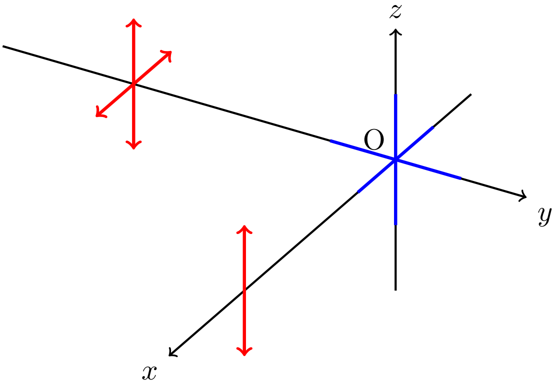
$\vec{x}, \vec{y}, \vec{n}, \vec{x'}$ same plane

Geometric representation

- Anisotropic radiation creates a net dipole moment in scattering atoms or molecules (Rayleigh scattering)
- shorter wavelengths more scattered

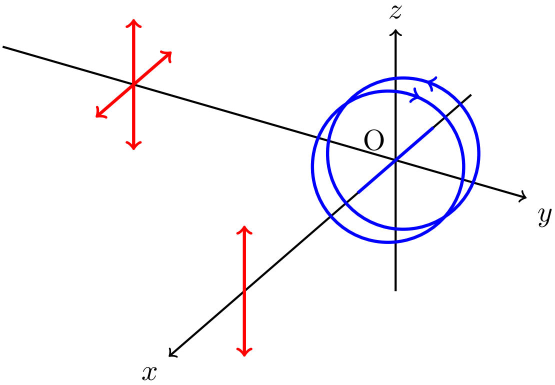
Geometric representation

Incident unpolarized light, cartesian oscillators



Geometric representation

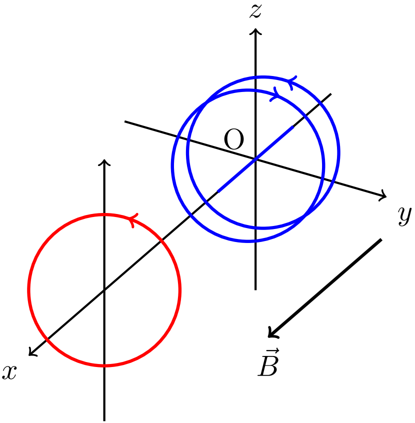
Incident unpolarized light, circular oscillators



coherence between circular oscillators

Geometric representation

Magnetic field along l.o.s , circular oscillators



ciclotron radiation

Geometric representation

Unpolarized incident light and magnetic field along l.o.s , circular oscillators

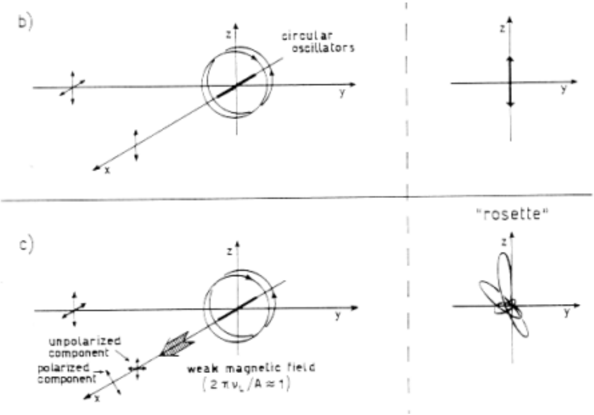


Figure 1: Incoherence in the circular oscillators - Hanle effect

Quantic representation (bound electron)

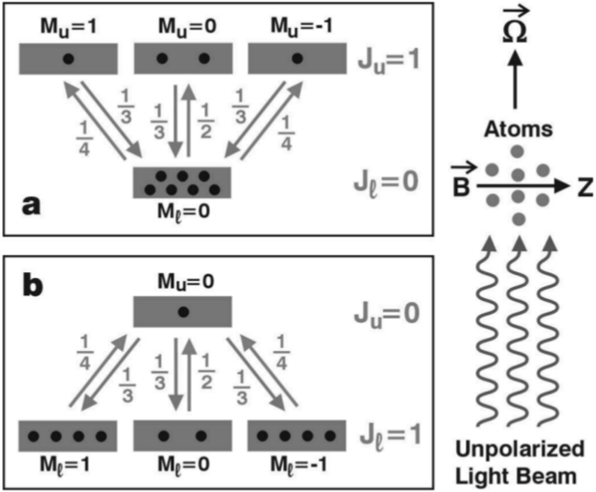


Figure 2: Emission/Absorption

Quantic representation (bound electron)

- Correspondence between atomic transitions and radiation components
  - $\Delta M = 1$, σ_+ $(\nu + \nu_L)$, clockwise oscillator
  - $\Delta M = 0$, π (ν), x oscillator
  - $\Delta M = -1$, σ_- $(\nu - \nu_L)$, anticlockwise oscillator
- similar mechanism(Fig 2 b) for absorption lines (experimetally done by observing same line in filaments: absorption and in prominences: emission)
- Anisotropic radiation populates/depopulates twice M=0 sublevel
- Magnetic field:
  - splitting of energy level J into 2J+1 sublevels (Zeeman effect)
  - creates incoherence between population of levels corresponding to σ components which leads to incoherence in the 2 circular oscillators (Hanle effect)

With the same geometry: Q represents linear polarization parallel to the closest limb

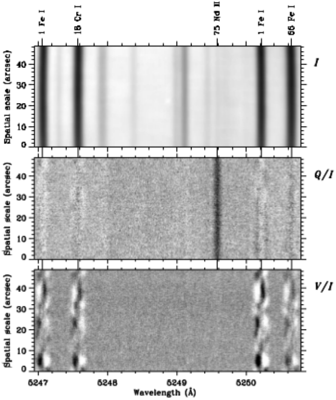


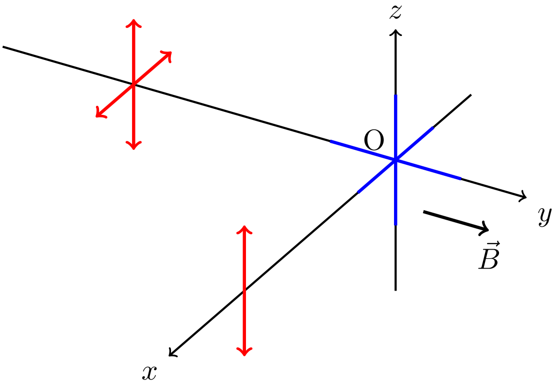
Fig. 1. Examples of the different characters of the ordinary intensity spectrum (Stokes I, top diagram), the linearly polarized spectrum (Stokes Q/I, here called the "second solar spectrum"), and the circularly polarized spectrum (Stokes V/I, bottom diagram). While the circular polarization shows Zeeman-effect signatures due to magnetic canopies at the supergranulation size scale, the linear polarization is dominated by the signature of coherent scattering, which here unexpectedly is due to a transition in ionized neodymium. The recording

Second specter of the sun

Unknown I 0 level
Eliminating Q signal generated by other mechanisms

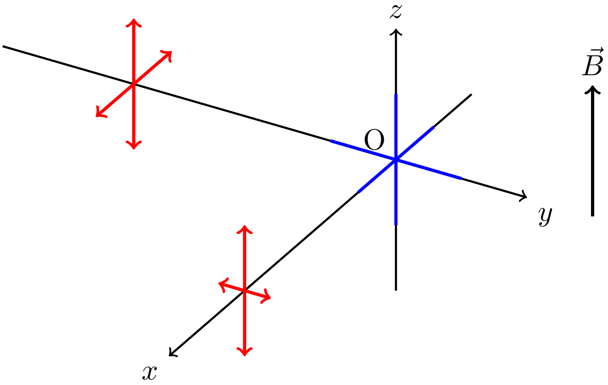
- atmospheric seeing and CCD noise: resolved by modulating the signal at high frequency: 2 modulators one at 42 kHz and 84 kHz
- position near the (geographic) north/south pole where influence of the magnetic field is smaller
- cross talk Stokes V generated by the magnetic field recognized (sign reversed with spatial period = the size of a granulation) which confirms the existence of horrizontal magnetic field oriented along the line of sight
- vertical magnetic field
- horrizontal magnetic field perpendicular to line of sight
- polarization by reflection

Vertical magnetic field



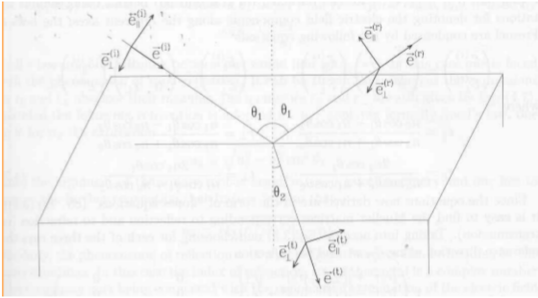
effect adding to that of the radiation: linear polarization (no V signal, no Hanle effect)

Horrizontal magnetic field, perpendicular to l.o.s.



horrizontal component(Hanle effect), no V signal

Polarization by reflection



Polarization by reflection

$$\boxed{\begin{pmatrix} E_{\parallel}^{(r)} \\ E_{\perp}^{(r)} \end{pmatrix} = \begin{pmatrix} r_{\parallel} & 0 \\ 0 & r_{\perp} \end{pmatrix} \begin{pmatrix} E_{\parallel}^{(i)} \\ E_{\perp}^{(i)} \end{pmatrix}}$$

$$r_{\parallel} = \frac{n_2 \cos\theta_1 - n_1 \cos\theta_2}{n_2 \cos\theta_1 + n_1 \cos\theta_2}$$

$$r_{\perp} = \frac{n_1 \cos\theta_1 - n_2 \cos\theta_2}{n_1 \cos\theta_1 + n_2 \cos\theta_2}$$

$$\boxed{\begin{pmatrix} E_{\parallel}^{(t)} \\ E_{\perp}^{(t)} \end{pmatrix} = \begin{pmatrix} t_{\parallel} & 0 \\ 0 & t_{\perp} \end{pmatrix} \begin{pmatrix} E_{\parallel}^{(i)} \\ E_{\perp}^{(i)} \end{pmatrix}}$$

$$t_{\parallel} = \frac{2n_1 \cos\theta_1}{n_2 \cos\theta_1 + n_1 \cos\theta_2}$$

$$t_{\perp} = \frac{2n_1 \cos\theta_1}{n_1 \cos\theta_1 + n_2 \cos\theta_2}$$

$n_1 = 1 < n_2, cos\theta_1 < cos\theta_2 \implies (n_2 cos\theta_1 = cos\theta_2 \implies r_{\parallel} = 0)$
$sin\theta_1 = n_2 sin\theta_2 \implies 1 - (cos\theta_1)^2 = n_2^2(1 - n_2^2(cos\theta_1)^2)$
$\theta_1 = arccos(\sqrt{\frac{n_2^2-1}{n_2^4-1}}) \implies$ reflected light polarized along $r_{\perp}$

Observation details

- instrument: ZIMPOL, the Zurich Imaging Stokes Polarimeter
- telescope: McMath-Pierce(National Solar Observatory (Kitt Peak, USA).)
- accuracy: 10^{-5}
- April 1995, slit positioned 5 seconds of arc inside the north polar limb (where the cosine μ of the heliocentric angle is 0.1)